State-based Ranking of Watersheds Using the Synoptic Assessment of Wetland Function Model

Final Report

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Table of Contents

List of Figures

Introduction and goals

A synoptic assessment of wetland function was recently completed in the four states that comprise EPA Region 7 (Schweiger et al. 2002). The synoptic approach attaches variables linked with wetland function to 8-digit hydrologic units (HUCs) and then uses those variables in different combinations to rank the HUCs. The goal was to identify 8-digit HUCs within the four-state region in which regulatory action would likely have the most benefits for conservation of wetland biodiversity. Five indicators of habitat quality and two indicators of species sensitivity were combined in different ways to derive three indices. Thus, three index values were attached to each 8-digit HUC and the HUCs were ranked in terms of wetland importance across Region 7.

The purpose of this project is to revisit the synoptic model using updated data and, in addition to a region-wide assessment, to rank watersheds on a state-by-state basis. The project uses indicator variables and indices that were previously used in the Region 7 synoptic assessment by Schweiger et al. (2002). However the data sources and software used for variable calculations differ in some instances. The study area is the four states in EPA Region 7: Missouri, Kansas, Iowa, and Nebraska (Figure 1). There are 241 HUCs, or sub-basins (obtained from the U.S. Geological Survey), that form the basic study units. All 8-digit HUCs that touch Region 7 were included in the study. The complete HUC boundary was retained rather than being clipped at state boundaries.

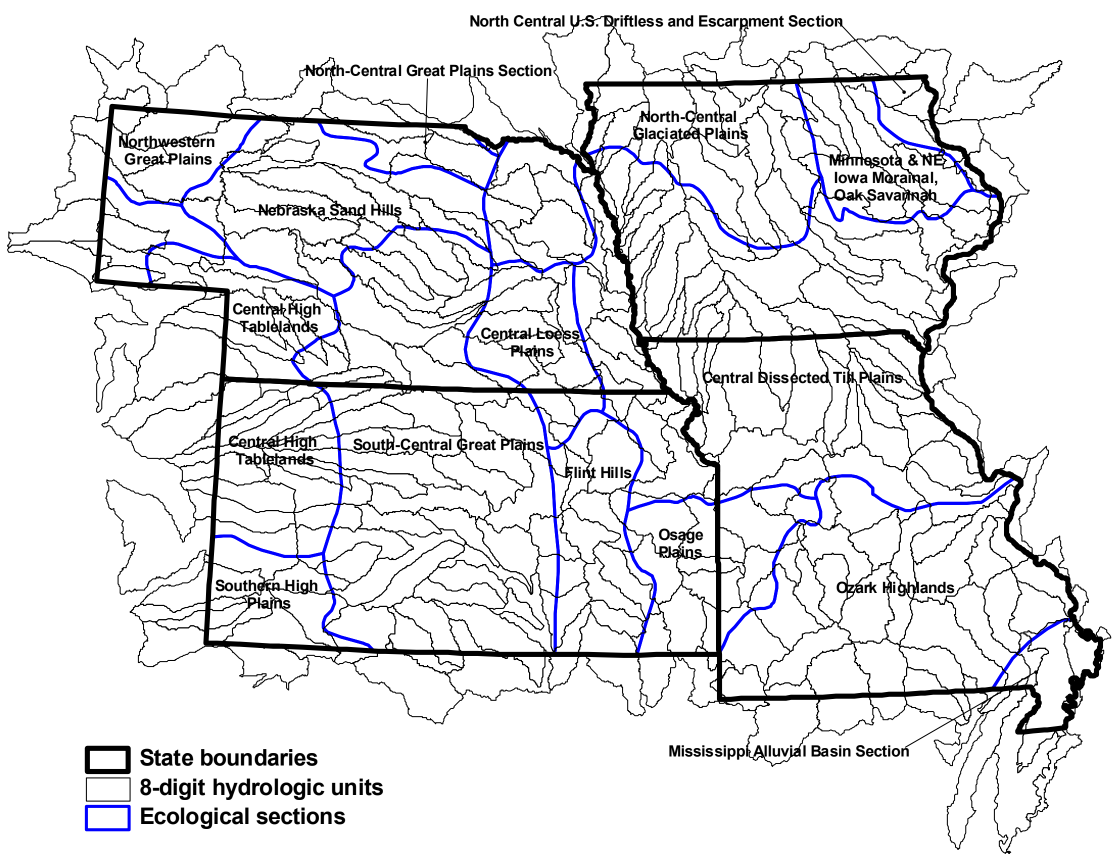

Figure 1. EPA Region 7 study area.

In the previous synoptic assessment for Region 7 three different indices were used to prioritize sub-basins (Schweiger et al. 2002). In the first index two, indicators relating to wetland habitat quality (agricultural density and wetland density) are combined. Index 2 combines five indicators relating to wetland habitat quality: agricultural density, wetland density, wetland habitat diversity, mean distance between wetland patches, and mean wetland patch size. Index 3 uses indicators relating to wetland species sensitivity: the heritage species global rarity score and a modifier to the global rarity score based on the five habitat indicators used in Index 2. In addition to the sensitivity indicators endemism scores for each species are used in the sub-basin ranking for Index 3. Schweiger et al. (2002) found strong correlation and similar spatial patterns in the ranks between all three indices. Index 3, which places emphasis on wetland species occurrences and variation in sub-basin wetland habitat quality, was used for this study. Each sub-basin has a final index value calculated by summing across all species (*i*) in sub-basin (*j*):

$$\sum_{i}\left[S\left(G_i + Q_j\right)\left(\frac{1}{N_i}\right)\right]$$

where S = species sensitivity value
G_i = Global rarity score for species *i*
Q_j = habitat quality modifer for sub-basin *j*
N_i = endemism value for species *i*

Habitat indicators

The five habitat indicators were calculated using data from the National Land Cover Dataset (NLCD) 1992-93 30-meter satellite thematic mapper imagery. Out of the 21 land cover categories only those related to wetland and agriculture were used for this study. Classes considered agriculture included row crops, small grains, and fallow land cover. Wetland classes included open water, woody wetlands, and emergent herbaceous wetlands. The NLCD was compared to the National Wetlands Inventory data, a U.S. Fish & Wildlife Service national mapping project of wetlands, and no significant differences were found in wetland density, patch size, or diversity (See Appendix A for a complete review of the comparison). The NLCD was used in developing the five habitat indicators, calculated within each sub-basin.

Agricultural density

Agricultural density is defined as the percent of all agricultural land within a sub-basin. Values range from 0.03 to 88.29% for sub-basins within Region 7. The sub-basins with the greatest amount of agricultural land (greater than 69.17%) are in the North-Central Glaciated Plains of Iowa and eastern Nebraska and the Mississippi Alluvial Basin in southeastern Missouri (Figure 2). The Ozark Highlands in southern Missouri and the Sand Hills and Northwestern Great Plains in Nebraska contain sub-basins with the lowest agricultural densities (less than 16.44%).

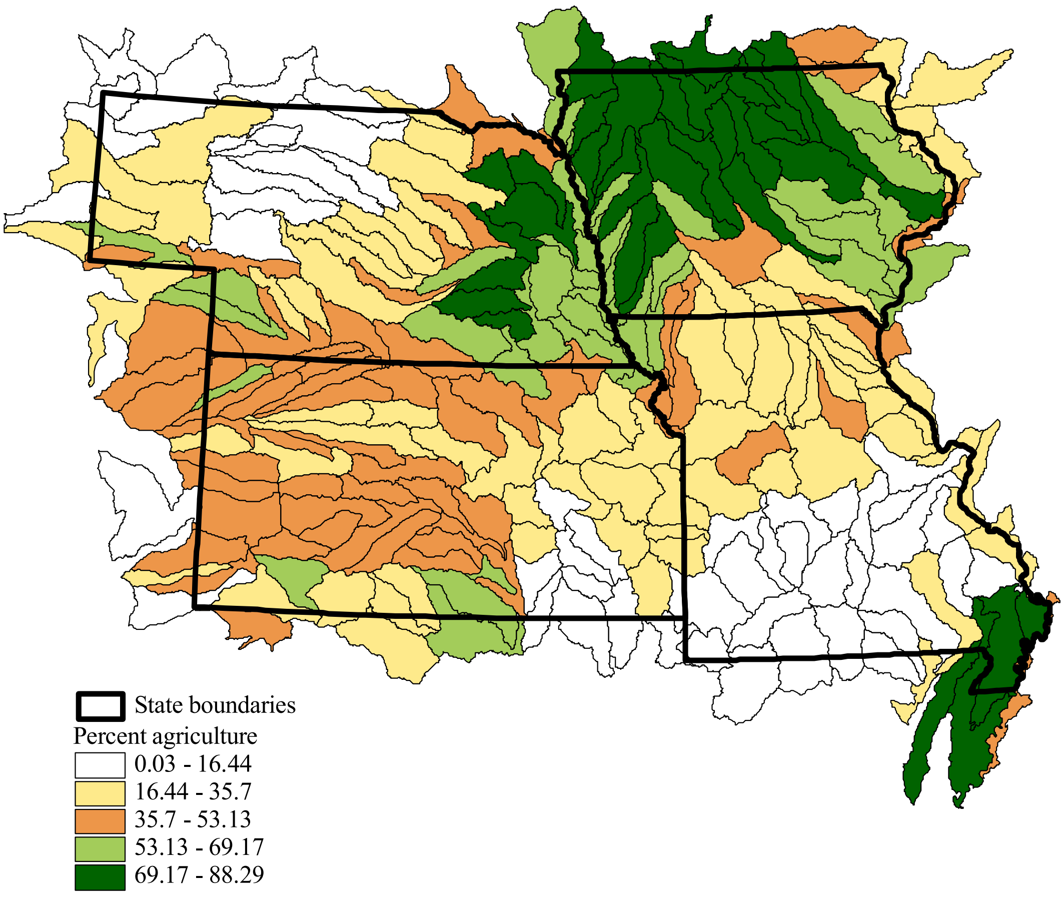

Figure 2. Agricultural density by sub-basin.

Wetland density

Wetland density is defined as the percent of all wetlands within a sub-basin. Values in Region 7 range from 0.01 to 47.8%. The sub-basins with the greatest amount of wetlands (greater than 7.20 %) are in the Nebraska Sand Hills, along the Mississippi River in eastern Iowa and Missouri, and, in north central Missouri in the Central Dissected Till Plains (Figure 3). Kansas contains sub-basins with some of the lowest wetland densities (less than 1.83%). In many cases those sub-basins with low agricultural density have relatively high wetland density.

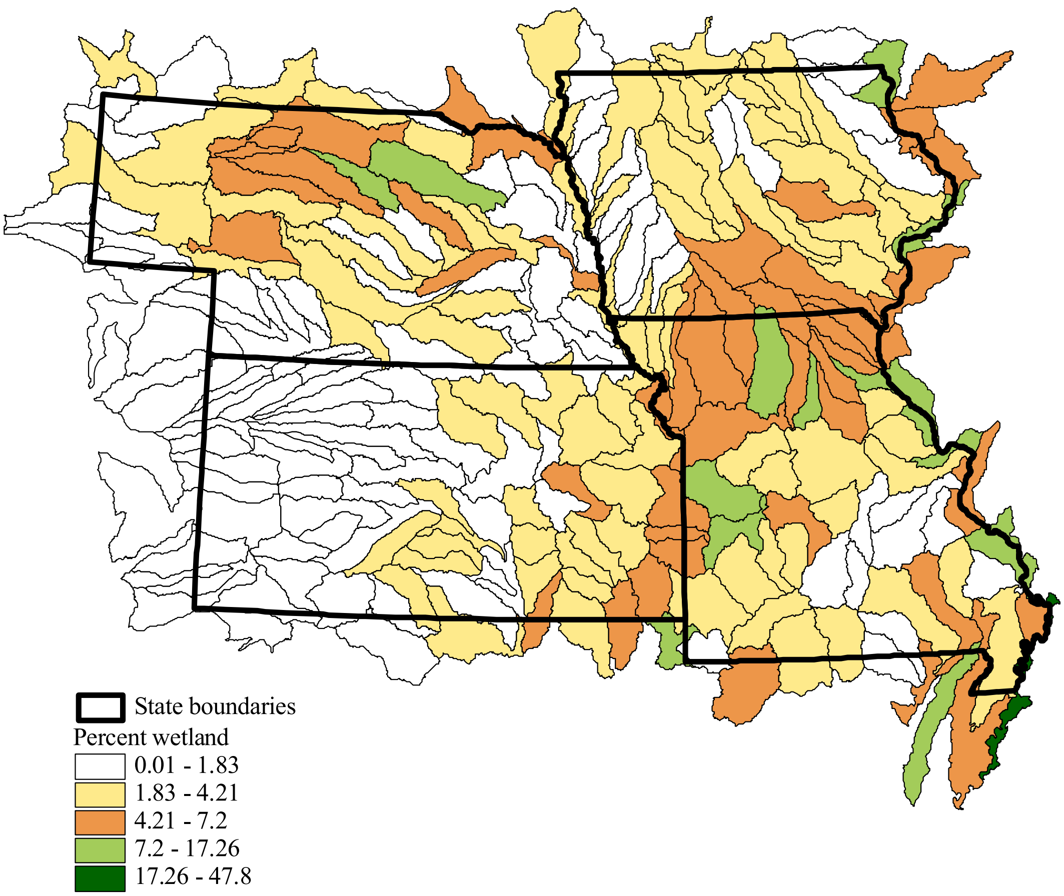

Figure 3. Wetland density by sub-basin.

Wetland diversity

Wetland diversity was calculated in Fragstats 3.3 (McGarigal and Marks 1995) using the three wetland categories defined in the NLCD: open water, woody wetlands, and emergent herbaceous wetlands. Shannon's diversity index represents the proportion of the landscape occupied by each wetland patch type. Diversity values begin at zero (low diversity) and increase as diversity increases. The sub-basins with the greatest diversity occur in northern Iowa and along the Nebraska-Iowa and Kansas-Missouri borders (Figure 4). Although some sub-basins, such as those in central Kansas, have a low wetland density, wetland diversity is relatively high. This is due to the even proportion of wetland patch types in those sub-basins, even though they are few of them. Sub-basins with the lowest diversity occur in western Kansas, in northern Nebraska in the Sand Hills, and in the southern edge of Missouri.

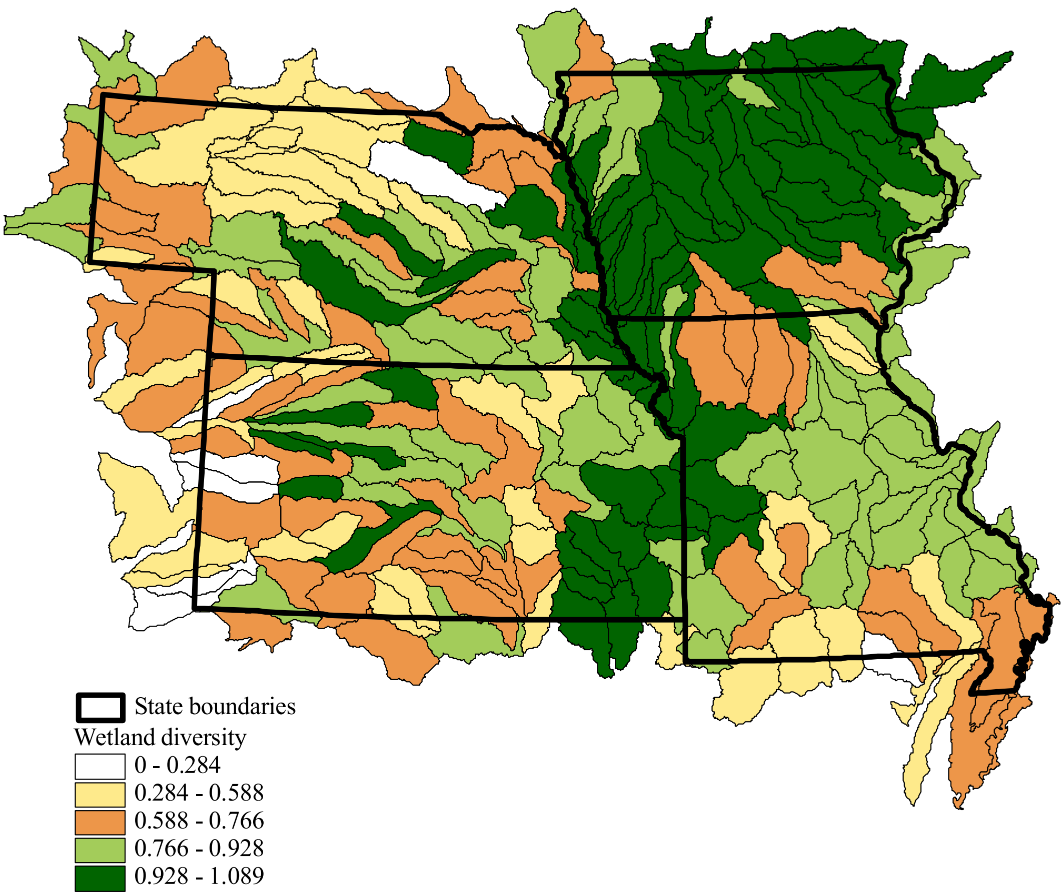

Figure 4. Wetland diversity by sub-basin (Shannon's diversity index).

Mean distance between wetland patches

The mean distance between wetland patches was measured in Fragstats 3.3 (McGarigal and Marks 1995) using the mean nearest neighbor function. This function measures the distance from one wetland patch to its nearest neighbor (edge-to-edge) and takes the average of all patch distances for the entire sub-basin. Mean nearest neighbor was weighted by the inverse of the number of wetland patches in the sub-basin. This weighting was done in the previous assessment to correct for differences in wetland patch density among sub-basins. The sub-basins with the greatest distance between wetland patches (weighted by the number of patches) occur in the western portions of Kansas and Nebraska (Figure 5). Many of the sub-basins (at least 209 of the 241 HUCs) have values less than 0.123 meters/number of patches.

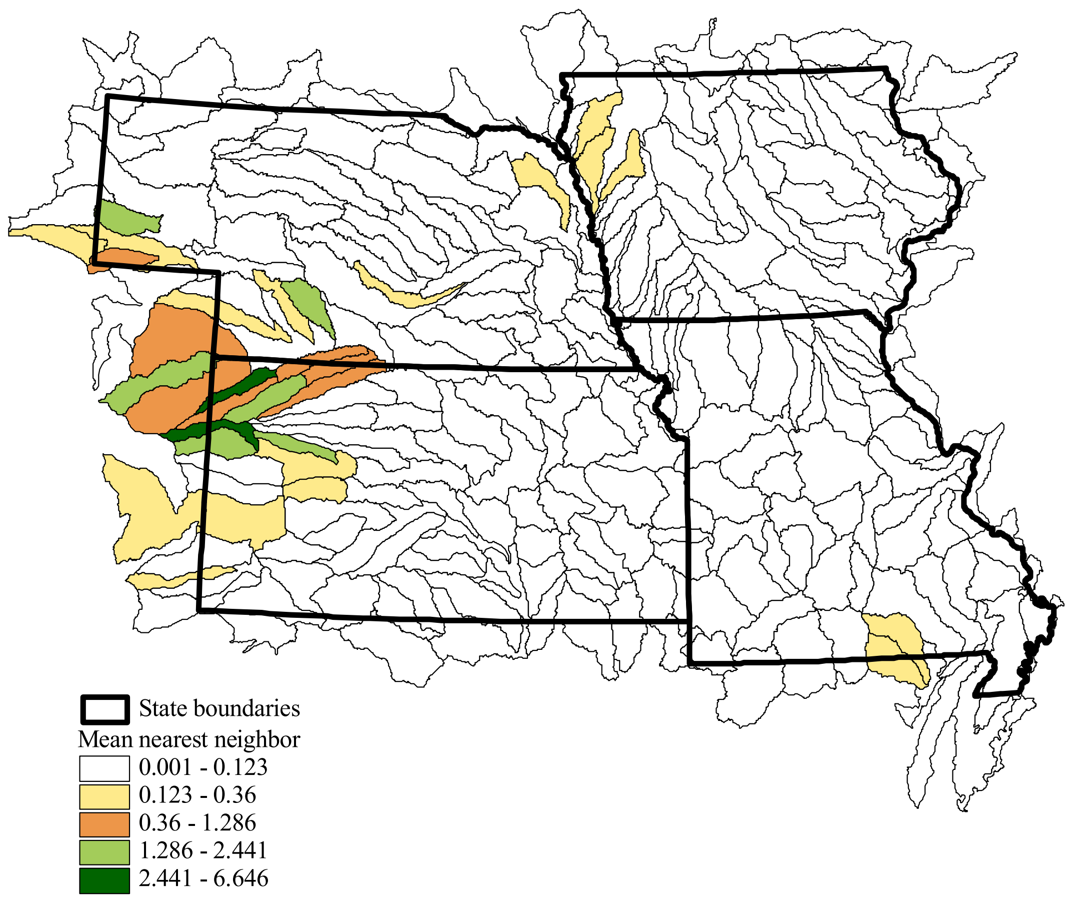

Figure 5. Mean distance between wetland patches by sub-basin (weighted by the inverse of the wetland patch frequency).

Mean wetland patch size

Mean wetland patch size was measured in Fragstats 3.3 (McGarigal and Marks 1995) which calculated the average of wetland patch size in a sub-basin. For Region 7 mean wetland patch size ranges from 0.242 to 12.108 hectares (Figure 6). Sub-basins containing the largest wetland patches on average are located in the Mississippi Alluvial Basin in southern Missouri, along the Mississippi River in Missouri and Iowa, and western Kansas and Nebraska. In general the smallest wetland patches are often located in the sub-basins with low wetland density.

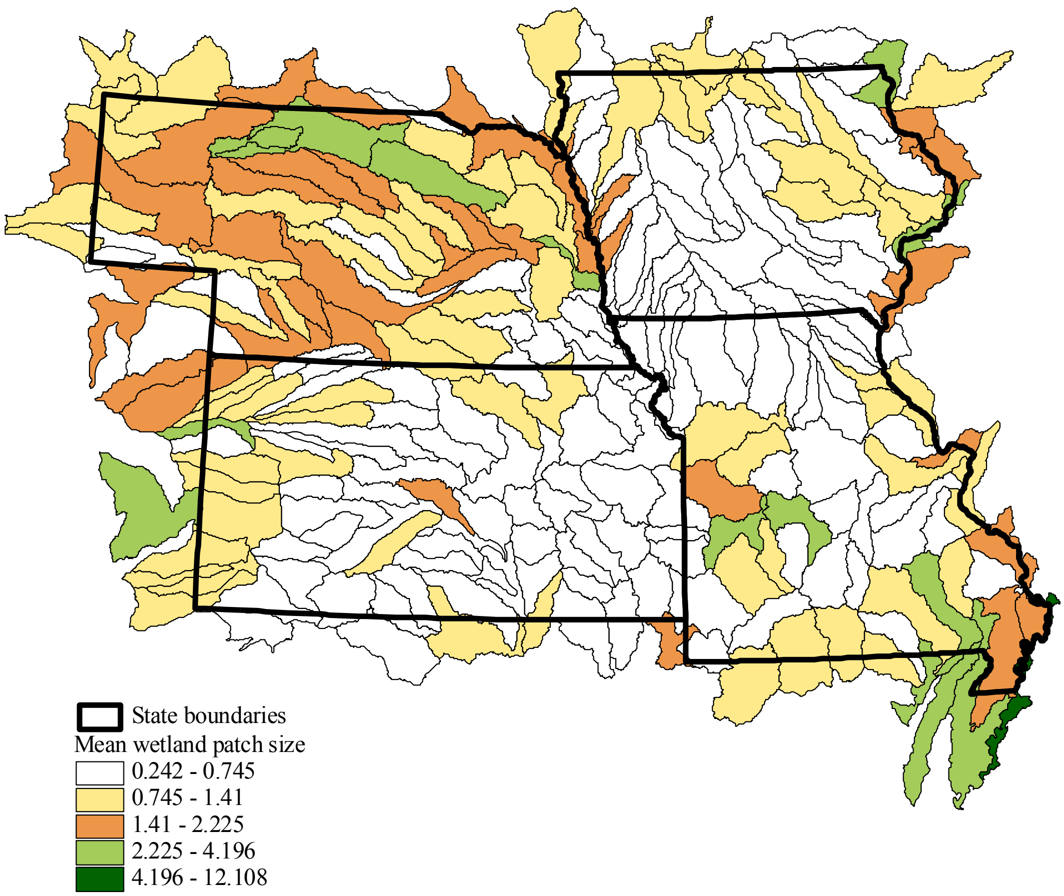

Figure 6. Mean wetland patch size by sub-basin.

Species sensitivity indicators

Species sensitivity indicators were evaluated from the 1995 Natural Heritage Program data base. The global rarity field (G-rank) ranks species from common (a designation of G5) to rare (a G1 designation). Wetland species were recorded at 3,071 points in Region 7 (with 264 unique species). Based on a species global rarity rank a score (determined by Schweiger et al. 2002) was assigned to each species. However, before the score was assigned, species were evaluated based on the wetland habitat quality within the sub-basin where they exist. The sensitivity scores were modified by the five habitat indicators.

Global rarity score

The global rarity score was calculated using a ranking system previously determined by Schweiger et al. (2002), which assigned each G-rank a value based on the median number of viable occurrences. The scores are as follows:

G-rank	Score
G1	1000
G2	250
G3	50
G4	25
G5	10

However, before final scores were assigned the G-ranks were modified by the habitat indicators.

Habitat quality categorical modifier to the global rarity score

Habitat indicators were evaluated in each sub-basin using principal components analysis (PCA). The five indicators of agricultural density, wetland density, wetland diversity, mean distance between wetland patches, and mean wetland patch size were first rank adjusted to normalize values. For the principal components analysis inverse values for agricultural density and mean distance between wetland patches were used to maintain consistency between indicators. Therefore, a high value of an indicator corresponded to favorable wetland habitat. A sub-basin with high wetland density, high wetland diversity, high mean wetland patch size, low agricultural density, and low mean distance between patches indicates favorable wetland habitat. Once the values were rank adjusted PCA was completed.

The loading factors for axis 1 and axis 2 were plotted (Figure 7) and used to determine habitat quality for each sub-basin. Sub-basins that fell within quadrant 2 and quadrant 3 were considered quality wetland habitat. These sub-basins had low agricultural density, high wetland density, high wetland diversity, low mean distance between wetland patches, and high mean wetland patch size. Meanwhile sub-basins within quadrant 1 and 4 were considered poor quality wetland habitat. If PCA values for a sub-basin were less than 1 standard deviation from the mean PCA loading scores they were considered neutral and assigned a value of zero (0). Sub-basins greater than 1 but less than 2 standard deviations from the mean were assigned a modifier value of 1 or –1 (positive if it fell within quadrant 2 or 3, negative if within quadrant 1 or 4). Sub-basins greater than 2 standard deviations from the mean had a modifier value of 2 or –2. Each sub-basin possessed a modifier to the G-rank based on habitat indicators.

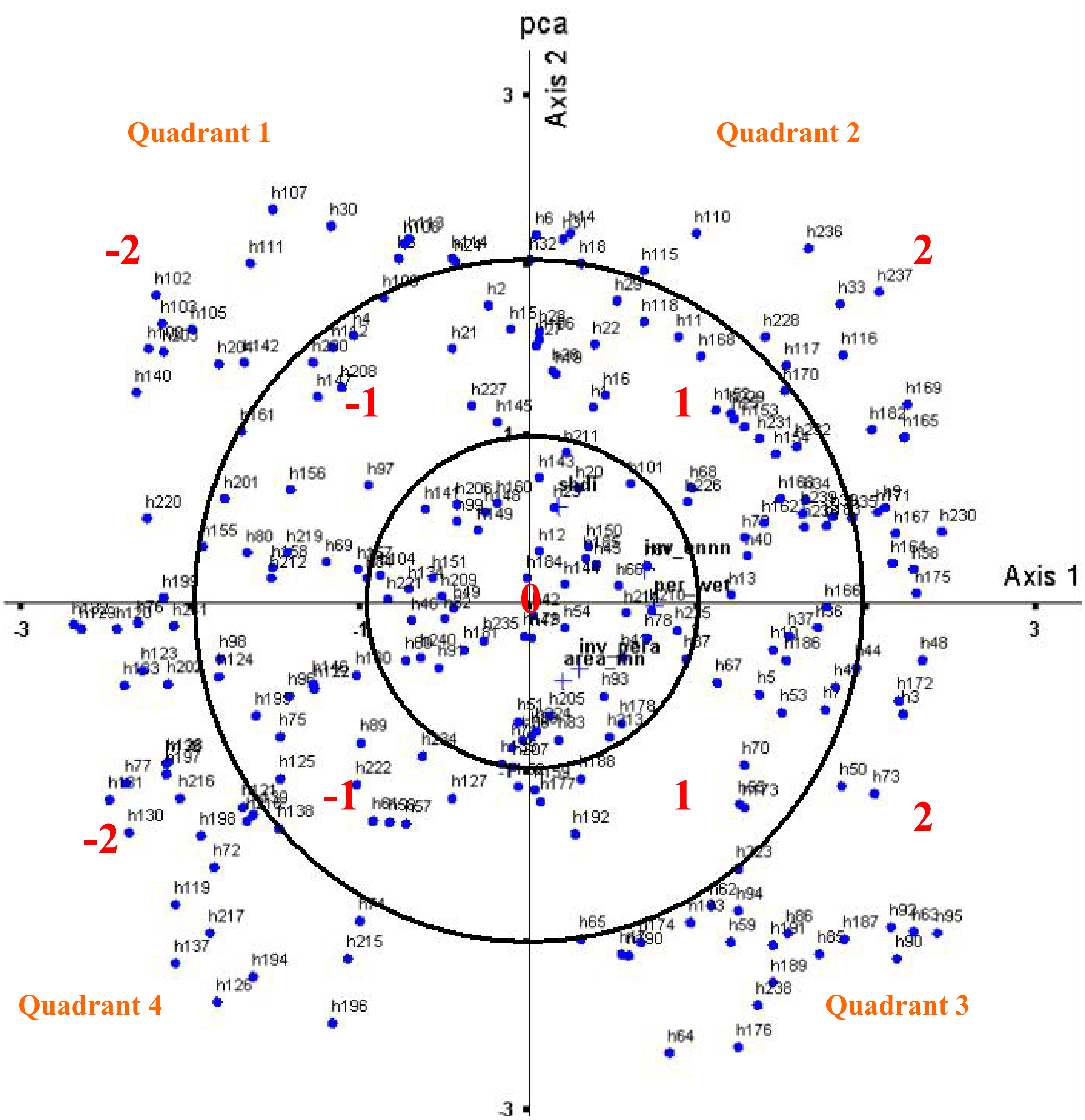

Figure 7. PCA scatterplot of Axis 1 and Axis 2 of habitat indicators. The location of each sub-basin on the plot defines the modifier score assigned to it. Each blue dot represents a sub-basin. The dark circles mark standard deviation boundaries. Values in red indicate the final modifier scores for each sub-basin.

The modifier value was used to adjust the G-rank scores of G1, G2, G3, G4, or G5. If a species fell within a sub-basin with a modifier of zero (0) the G-rank score remained the same. If it had a –1 a species with a G-rank of G1 would be a G2. If it were a 2 the species would have a modified G-rank of –G1. Additional G-ranks were added to compensate for the newly modified ranks. The final scores included a range from –G1 to G7:

Global rank	Score
-G1	7500
G0	3000
G1	1000
G2	250
G3	50
G4	25
G5	10
G6	5
G7	1

Endemism

If a species occurs in multiple sub-basins the risk of regional extirpation is low if the species were to experience a local loss. Endemism was calculated as $1/N_i$, where N is the number of sub-basins that the species occurs within the region.

Regionwide synoptic assessment results

The results produced from Index 3 rank the 241 sub-basins in Region 7. Visual review of the results indicates that priority sub-basins occur in clusters throughout the region (Figure 8). Highest rankings occur in the Ozark Highlands of Missouri, The Osage Plains in eastern Kansas, the Nebraska Sand Hills, and the Minnesota & NE Iowa Morainal, Oak Savannah in northeastern Iowa. Wetland density appears to play a small role in the final ranking. High wetland density, diversity, and patch size appear to contribute to a higher final ranking. When compared to the initial assessment conducted by Schweiger et al. (2002) Index 3 rankings for both assessments show similar patterns. The sub-basins were assigned a numerical rank from 1 to 241 reflecting highest to lowest index values.

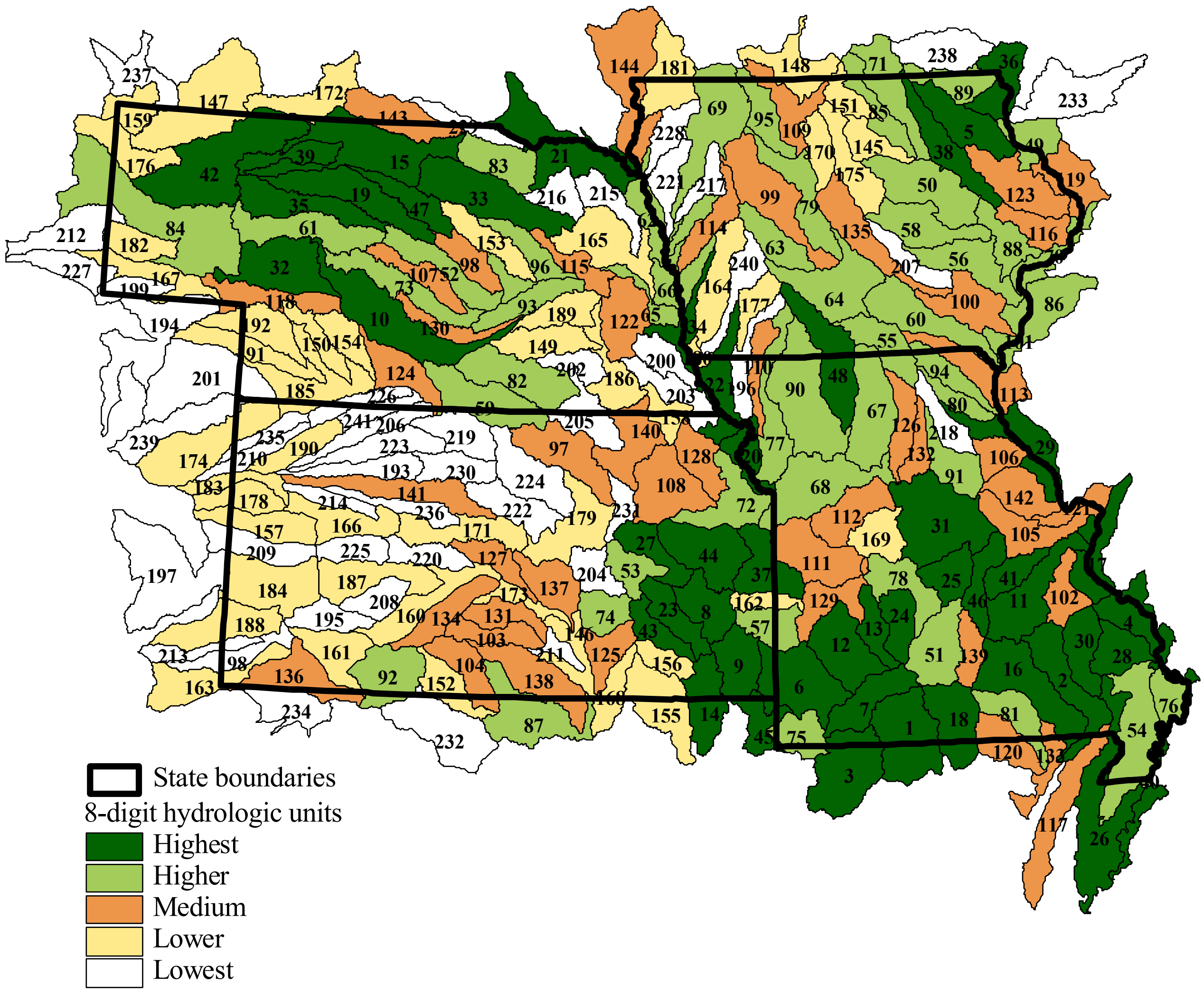

Figure 8. Index 3 ranks of 8-digit hydrologic units within Region 7. Classification of the final numerical ranks use the Fischer-Jenks natural breaks method.

Statewide synoptic assessment results

In addition to ranking the sub-basins on a regional level, sub-basins were ranked on a state level. Ranking sub-basins on a statewide level allows each state to set wetland priorities relative to their state boundaries. The same formula for Index 3 was used, along with each G-rank and habitat modifer for each sub-basin. Endemism scores were re-calculated on a statewide level. Endemism was calculated as before but only using HUCs within the state of interest rather than the entire region. All 8-digit hydrologic units that touched or were within the state boundary were considered in the statewide assessment. Complete sub-basins were used for the statewide analyses along with heritage data extending to the full extent of the hydrologic units. Numerical ranks were re-adjusted to reflect state level sub-basin priorities.

Missouri

Some of the highest priority sub-basins in Missouri occur in the Ozark Highlands (Figure 9). The sub-basins in the southwest portion of the state contain some of the largest lakes in Missouri, including Table Rock, Bull Shoals, and Truman lakes. The density and size of these lakes indicate the weight that some habitat attributes have on the final ranking. Sub-basins with the lowest priority are scattered throughout the state. These sub-basins appear to have lower endemism values or lower modified global rarity scores.

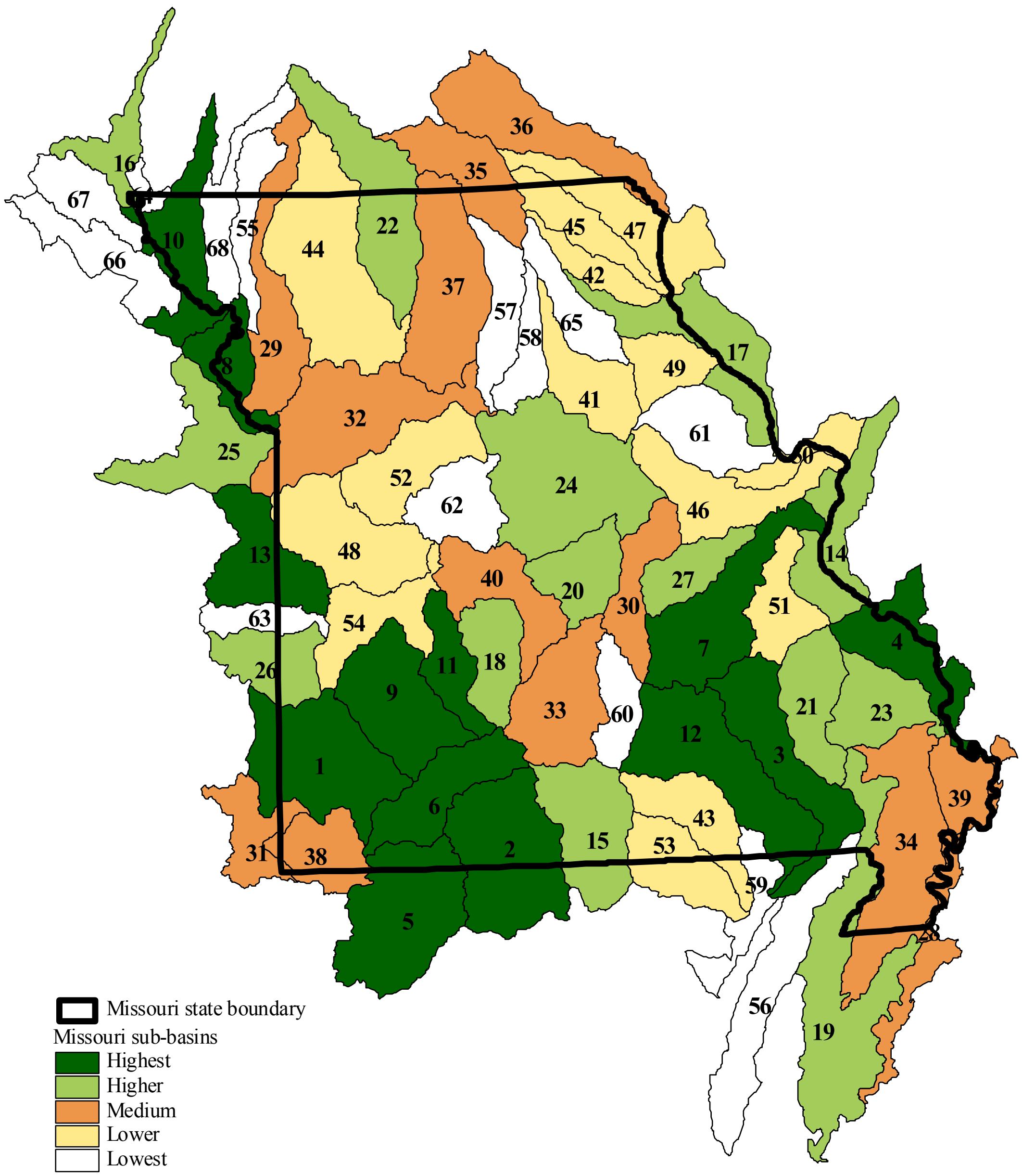

Figure 9. Index 3 ranks of 8-digit hydrologic units within Missouri. Classification of the final numerical ranks use the Fischer-Jenks natural breaks method.

Kansas

The sub-basins with highest priority in Kansas occur in the Osage Plains and Central Dissected Till Plains subsections in the eastern portion of the state (Figure 10). These sub-basins contained many, larger bodies of open water along with some woody and herbaceous wetlands. From central to western Kansas sub-basins are lower in priority. In these sub-basins there are relatively few wetlands or wetland species.

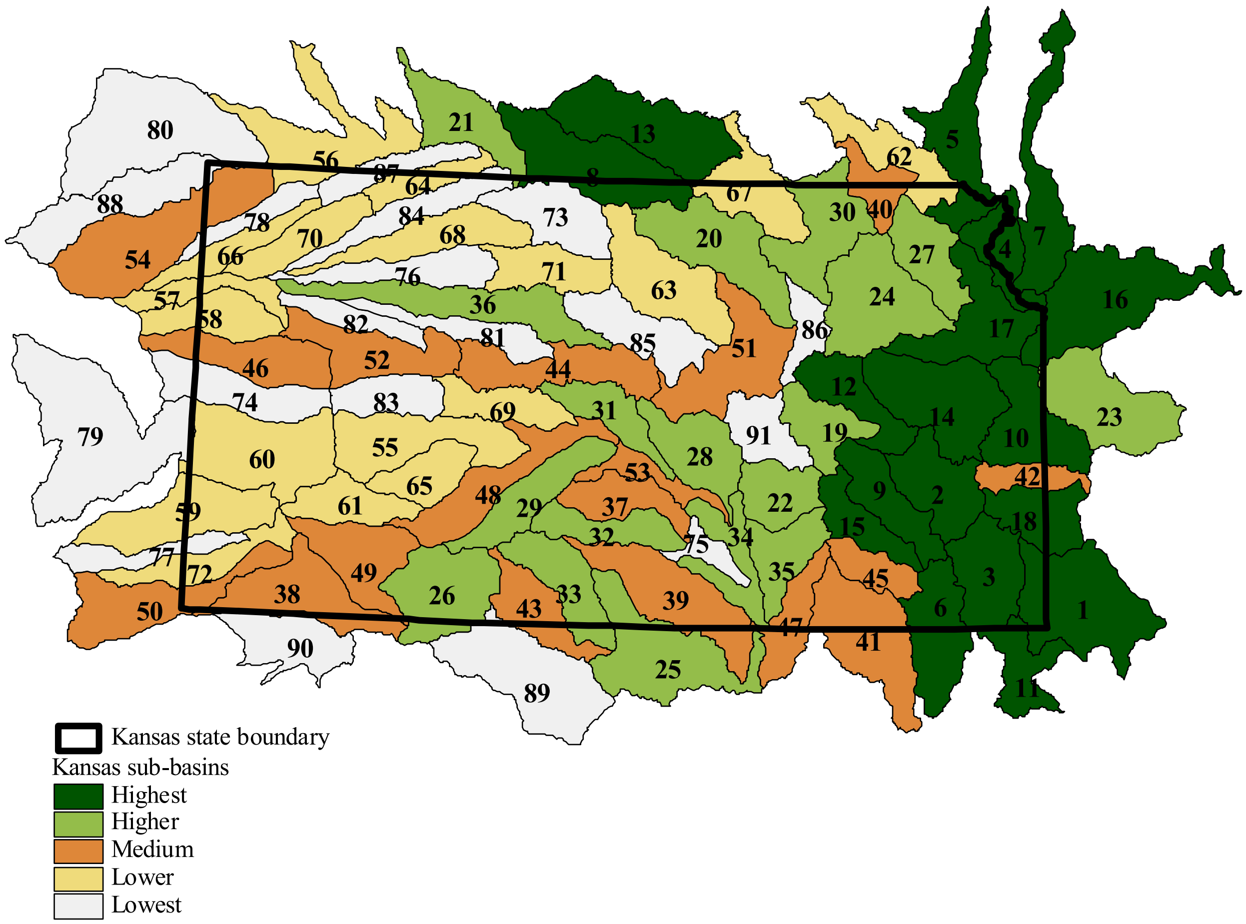

Figure 10. Index 3 ranks of 8-digit hydrologic units within Kansas. Classification of the final numerical ranks use the Fischer-Jenks natural breaks method.

Iowa

Sub-basins with the highest ranks occur in the Mineesota & NE Iowa Morainal, Oak Savannah subsection and the Central Dissected Till Plains (Figure 11). These subsections appear to contain a greater number of wetland species with higher modified G-rank scores. The sub-basins with the lowest priority are scattered throughout the state. These sub-basins tend to contain few wetlands and few wetland species.

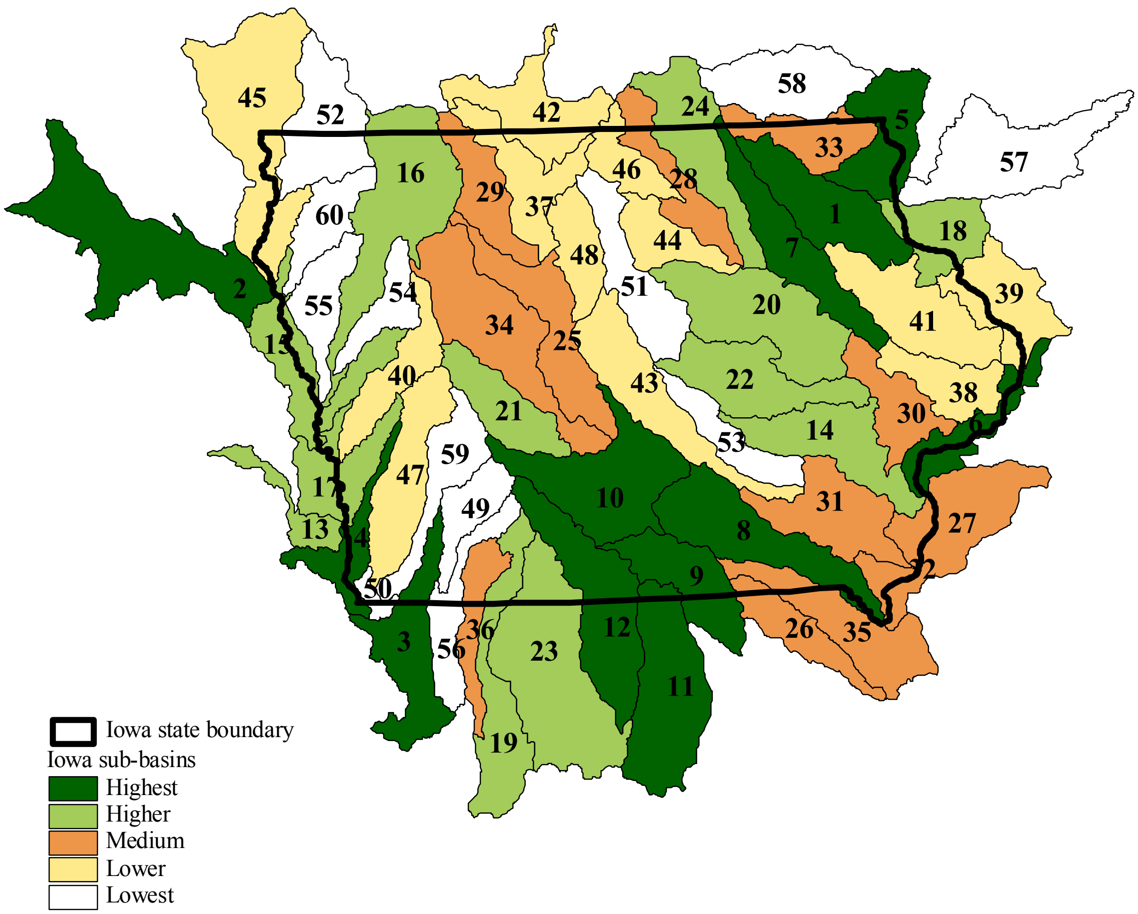

Figure 11. Index 3 ranks of 8-digit hydrologic units within Iowa. Classification of the final numerical ranks use the Fischer-Jenks natural breaks method.

Nebraska

Sub-basins in the Nebraska with the highest priority ranking occur in the central region of the state, primarily in the Sand Hills and the South Central Great Plains subsections (Figure 12). Many of the sub-basins contain a high density of emergent herbaceous wetlands, although the sub-basins in the southcentral portion of Nebraska (ranked 9th and 10th) contain very few wetlands. These sub-basins do contain numerous wetland species with relatively higher modified G-rank scores. Sub-basins with lowest ranking occur primarily outside of the central region of the state. These areas tend to have low wetland density and low wetland species presence.

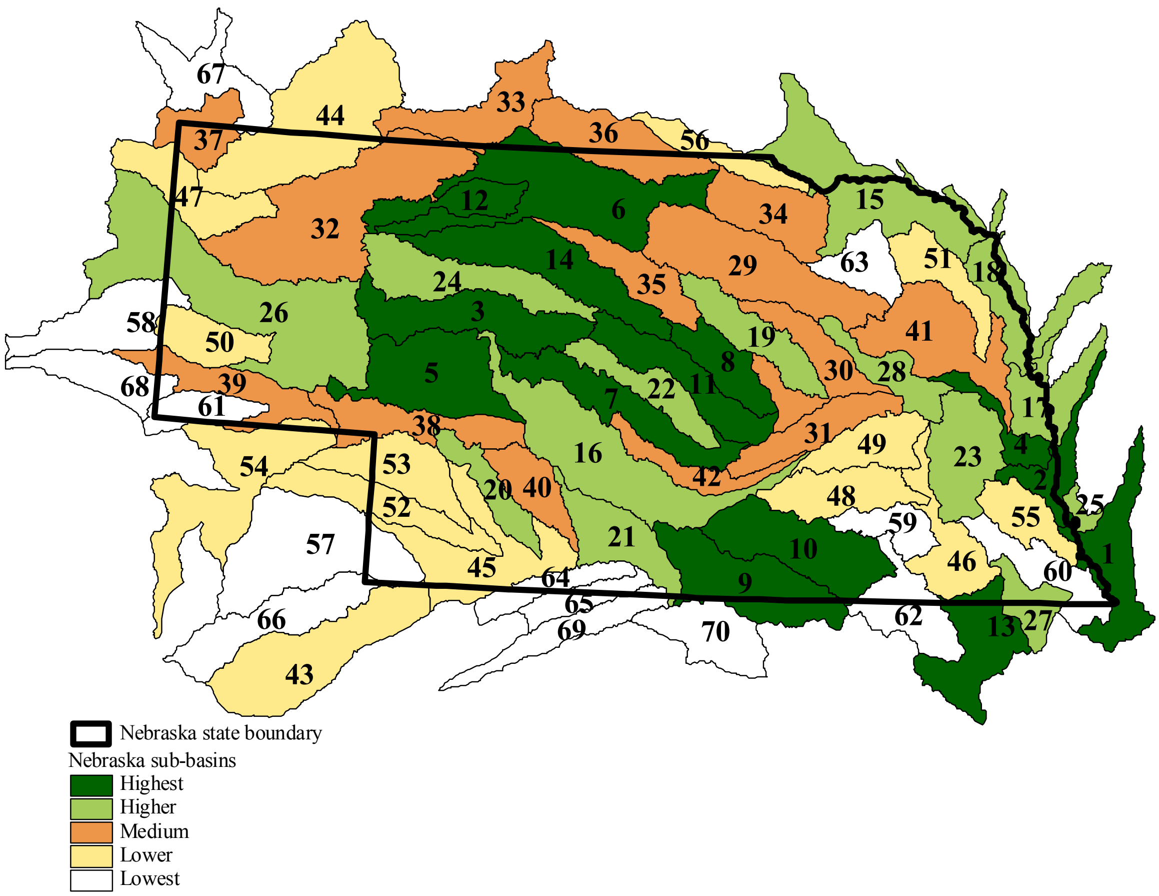

Figure 12. Index 3 ranks of 8-digit hydrologic units within Nebraska. Classification of the final numerical ranks use the Fischer-Jenks natural breaks method.

Discussion

The prioritization of wetlands in this study was the result of a complex weighting of habitat quality and species sensitivity indicators. In different instances different indicators seemed to contribute more heavily to the ranking of wetlands. Endemism appeared to be a driving force along with the Global rarity scores. It can be difficult to determine a single feature driving the prioritization of a sub-basin. Habitat indicators, used to modify the Global rarity scores, also appeared to have some impact on assessment results. In particular, patterns in wetland density and wetland patch size seemed to correspond to prioritization of sub-basins.

Results for the sub-basins on the outer borders of Region 7 may be altered due to the lack of availability of Heritage data for this region. In these instances more species may exist in portions of the sub-basins that fall outside of Region 7. However, due to lack of data availability, this information was not available. The assessment used only available data within the Region.

Prioritization of sub-basins at the state level added more information to the wetland assessment. Sub-basins that rank lower at a regional level, ranked higher once considered strictly within state boundaries. This additional information should be valuable for many state-based programs and initiatives.

In the future, ranking of large polygons such as 8-digit HUCs may provide insufficient resolution for some applications. Data are available at 30-meter pixel resolution. Hence, more spatially-specific results could be achieved. Furthermore, advances in classification and conservation ranking of watersheds and riverine ecosystems are moving forward (e.g. the Missouri Aquatic Gap Analysis Project) and results do provide better information on riverine resources.

References

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Schweiger, E.W., S.G. Leibowitz, J.B. Hyman, W.E. Foster, and M.C. Downing. 2002. Synoptic assessment of wetland function: a planning tool for protection of wetland species biodiversity. *Biodiversity and Conservation* 11: 379-406.

Appendix A

The National Wetland Inventory (NWI) and the National Land Cover Data (NLCD) both provide data in a GIS format on the type and location of wetlands across the United States. For the purposes of this study the data within Missouri were compared to determine which source would be better suited for this study.

The NWI has three wetland categories: open water, woody wetland, and herbaceous wetland. The NLCD has three land cover categories that were considered wetland categories: open water, woody wetlands, and emergent herbaceous wetlands.

Within Missouri wetland percent was calculated for NWI and NLCD by sub-basin. Values ranged from 0.10 to 45.17% for NWI and 0.17 to 46.78% for NLCD. For each sub-basin there was less than a 3% difference in the percent of wetland between NWI and NLCD. In addition to comparing the percent of wetland other habitat variables were also compared.

Wetland patch density, mean patch size, and diversity were calculated using Fragstats 3.3 (McGarigal and Marks 1995). The means within each sub-basin in Missouri were compared between NWI and NLCD. A t-test was used to determine if the differences in values were statistically significant.

	NWI	NLCD	p-value
Patch density	119.9	153.9	0.07
Mean patch size	1.28	0.83	0.08
Diversity	0.45	0.47	0.467

The means of each wetland measurement were not statistically different (p-value from T-test was greater than 0.05). Since the differences in values between NWI and NLCD were insignificant either data was considered suitable for use. Since the NLCD also contained information on agricultural land it was used as a consistent data source.